National Aeronautics and Space Administration

NASA
WESTERN WATER
APPLICATIONS
OFFICE

Columbia River Basin Needs Assessment Report

Tools for managing a precious resource

February 2020

Executive Summary

The National Aeronautics and Space Administration's (NASA) Western Water Applications Office (WWAO) contracted with SPF Water Engineering (SPF) to conduct a needs assessment of water stakeholders in and around the Columbia River Basin (CRB). The project commenced in March 2019 with a desktop study that summarized publicly available information about stakeholders who can potentially benefit from WWAO's remote-sensing research and data. Based on this information and feedback from WWAO, a series of interviews were conducted in April and May 2019 with twenty-two stakeholders who made up a representative cross section of policy makers, planners, water management officials, and end users within the CRB.

The goal of these interviews was to establish a greater understanding of the stakeholders' water resource responsibilities and current limitations to providing greatest value to their clients, customers, members, or constituents. Interviews were conducted with representatives from each stakeholder agency, a group characterized by both management/administrative personnel as well as technical/GIS staff. The survey data were used to identify important water management and data challenges within the CRB and information gaps that are impeding decision making progress.

In September 2019, stakeholders convened in Portland, Oregon for a Needs Assessment Workshop. The workshop allowed some NASA WWAO team members to meet with stakeholders to identify, prioritize, and catalog stakeholder needs, called "use cases", and discuss NASA resources and capabilities. An initial list of fifty-four water management needs were identified. The water management needs were separated into four broad water management categories, including Agriculture, Water Quality, Water Supply, and Watershed Health. Further discussion and analysis resulted in a final list of fourteen use cases to move forward for further study. The fourteen use cases are listed below, separated by category:

- Agriculture
  - Crop Mapping
  - Evapotranspiration/Consumptive Use
  - Irrigation
- Water Quality
  - Cyanobacteria
  - Stream Temperature
  - Turbidity
- Water Supply
  - Evapotranspiration
  - Groundwater Recharge & Storage
  - Snow Water Equivalent
  - Streamflow Monitoring
- Watershed Health
  - Habitat Management
  - Land Use & Land Cover
  - Surface & Groundwater Interaction
  - Stream Temperature Dynamics

Use cases are used to systematically analyze data needs for decision making and communicate those needs to technical developers. The use cases developed at the workshop are intended for assessing water resources needs with enough detail to develop projects and communicate those needs to NASA WWAO team members. Use cases were developed through discussions facilitated by WWAO and SPF team members. Discussions included careful consideration of water management needs and their relative importance. Use case development focused on how decision makers use data, thus ensuring the data were open, transparent, and relevant to the needs of the decision makers.

The format of the workshop included smaller use case discussion groups. Some discussion groups developed similar use case topics and project ideas. For example, both the Water Quality and Watershed Health groups developed use cases relating to stream temperature. Additionally, both the Agriculture and Water Supply groups developed use cases relating to evapotranspiration. At the end of the workshop, these use cases topics were combined at the recommendation of the stakeholders. Special attention should be given to these use cases because their scope crosses water management categories.

Discussions at the workshop were focused on the most important water management needs, as selected by stakeholders in attendance. As discussed later in this report, many important stakeholders were not present at the workshop. As such, many water management needs were not represented at the workshop and were not selected for use case development. For example, a few stakeholders noted drought forecasting was not developed into a use case, but is an important need throughout the CRB. In some instances, stakeholders that were not in attendance were identified as main decision makers or use case participants. Without their perspective on current capabilities, the use case information may be incomplete.

This report presents a summary of the workshop, the most significant water management needs identified, and the obstacles to meeting those needs. This information will provide the foundation for identifying priority stakeholders, strategies, and potential WWAO projects to overcome water management challenges facing the Columbia River Basin.

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List of Acronyms

ADVM – Acoustic Doppler Velocity Meter
ARS – Agricultural Research Service
ASO – Airborne Snow Observatory
BLM – Bureau of Land Management
BPA – Bonneville Power Administration
CHaMP – Columbia Habitat Monitoring Program
CRB – Columbia River Basin
CRITFC – Columbia River Inter-Tribal Fish Commission
CyAN – Cyanobacteria Assessment Network
DRI – Desert Research Institute
EOSDIS – Earth Observing System Data and Information System
EPA – Environmental Protection Agency
ESRI – Environmental Systems Research Institute
ET – Evapotranspiration
FLIR – Forward-Looking Infrared Radar
GRACE – Gravity Recovery And Climate Experiment
gridMET – Gridded Surface Meteorological Dataset
IDEQ – Idaho Department of Environmental Quality
IDFG – Idaho Fish & Game
IDWR – Idaho Department of Water Resources
LANDSAT – Land Remote-Sensing Satellite
LiDAR – Light Detection & Ranging
METRIC – Mapping Evapotranspiration using High Resolution and Internalized Calibration
MODIS – Moderate Resolution Imaging Spectroradiometer
NAIP – National Agriculture Imagery Program
NOAA – National Oceanic & Atmospheric Administration
NASS – National Agricultural Statistics Service
NGWMN – National Ground-Water Monitoring Network
NHS – National Hydrologic Services
NLCD – National Land Cover Database
NRCS – Natural Resources Conservation Service
NWFSC – Northwest Fisheries Science Center (NOAA)
ODEQ – Oregon Department of Environmental Quality
ODFW – Oregon Department of Fish & Wildlife
OSU – Oregon State University
OWEB – Oregon Watershed Enhancement Board
OWRD – Oregon Water Resources Department
RCD – Resource Conservation District
SAR – Smolt to Adult Ratio
SNOTEL – Snowpack Telemetry
SSEBOP – Simplified Surface Energy Balance
SWE – Snow Water Equivalent
TMDL – Total Maximum Daily Loads
TSS – Total Suspended Solids
USACE – U.S. Army Corps of Engineers
USBR – U.S. Bureau of Reclamation
USDA – U.S. Department of Agriculture
USFS – U.S. Forest Service
USFW – U.S. Fish & Wildlife
USGS – U.S. Geological Survey
UW – University of Washington
VELMA – Visualizing Ecosystem Land Management Assessments
WDE – Washington Department of Ecology
WDEQ – Washington Department of Environmental Quality
WDFW – Washington Department of Fish & Wildlife
WDNR – Washington Department of Natural Resources
WSU – Washington State University

1. INTRODUCTION

As part of its mission to help solve important water resource challenges facing the western United States, the National Aeronautics and Space Administration's (NASA) Western Water Applications Office (WWAO) wants to provide valuable remote-sensing-based information to decision-makers within the Columbia River Basin (CRB). SPF Water Engineering (SPF) has been tasked with assisting WWAO in its endeavor. This process involves identifying how water is currently managed within the CRB, cataloging major water stakeholders, and establishing a greater understanding of their water resource responsibilities and limitations to providing the greatest value to their clients, customers, members, or constituents.

1.1. The Columbia River Basin

The CRB is located in the Pacific Northwest region of the United States, and extends across parts of seven states and British Columbia, Canada with a total area of 258,000 square miles. The Columbia River, the largest river in the Pacific Northwest and the fourth largest river in North America, begins its journey in the Rocky Mountains of British Columbia. It travels more than 1,200 miles, being fed along the way by tributaries such as the Kootenai, Clark Fork-Pend Oreille, Willamette, Yakima, Deschutes, and Snake Rivers. The Columbia eventually forms the boundary between Washington and Oregon, until it drains into the Pacific Ocean near Astoria, Oregon.

The Columbia River and its tributaries have been largely controlled since 1909 through the construction and management of dams and reservoirs. Reservoir operations are coordinated for multiple objectives, including flood risk management, hydropower production, navigation, irrigation water supply, and ecosystem requirements. There are more than 100 dams within the CRB owned and operated by private and public utilities, 31 by the federal government, and many more by irrigation entities, states, and Canada [2]. Coordination amongst the different agencies and users, all with different interests, is accomplished through a number of treaties between the United States and Canada, interstate compacts, agreements, and laws.

The Columbia River and its tributaries are an integral part of the history, development, and economy of the CRB. Many of the communities, industries, and tribal interests in the region are dependent on the river system. The available groundwater resources have also proven invaluable to the overall success of the region by providing fresh water for irrigation, industrial uses, and communities.

Groundwater usage within the CRB is extensive. Some of the primary groundwater uses include irrigation and public supply/domestic use. In Idaho, agricultural irrigation accounted for approximately 90 percent of all groundwater withdrawal in 2015 [1]. Groundwater is the primary source of drinking water in Idaho, providing 89 percent of the state's drinking water. Similar numbers were found in Oregon [1]. To a greater extent than with surface water, groundwater within the CRB is managed by agencies within each state, sometimes in coordination with federal agencies. The primary groundwater management concerns for each state are related to water quality, water rights, well construction, and groundwater supply and forecasting.

Figure 1 – Columbia River Basin Map

Because of the important role water plays throughout the CRB, a great deal of coordination between the many entities and awareness of the unique challenges facing the region is necessary. Concerns that must be considered include salmon migration, agricultural demand, hydropower production, population growth, tribal interests, water rights, and renegotiation of the Columbia River Treaty.

2. PROJECT BACKGROUND

The project commenced in March of 2019 with a desktop study that summarized publicly available information about stakeholders who can potentially benefit from WWAO's remote-sensing research and data. This study culminated in an internal report containing a summary of the CRB and publicly-available information about CRB stakeholders. The report presented a total of 39 significant stakeholders in the CRB. Stakeholders were selected on the basis of their work within the CRB and their role in management of water resources in the CRB. The selected stakeholders included state and federal agencies, utility providers, educational institutions, municipalities, tribal organizations, non-profits, industries, and consortiums whose members represent varied and sometimes conflicting interests. Preliminary profiles were included in the report with information on each stakeholder organization, including policy making responsibilities, water management activities, and water usage. Additionally, information relevant to each stakeholder's mission, challenges, financials, and customer base was identified where available.

From the initial list of thirty-nine stakeholders, a representative cross section of twenty-two stakeholders was developed to participate in a series of interviews in April and May of 2019. Interviews were conducted with representatives from each stakeholder agency, a group characterized by both management/administrative personnel as well as technical/GIS staff. The goal of these interviews was to establish a greater understanding of the stakeholder organizations and the limitations they face to providing greatest value to their clients, customers, members, or constituents. The interview process culminated in an internal report containing in-depth stakeholder profiles, a summary of major water management challenges facing the CRB, and data gaps that prevent stakeholders from utilizing available remote sensing information to support management and planning decisions.

The most commonly noted water management challenge related to water distribution. Stakeholder respondents indicated that it is becoming increasingly difficult to balance water usage demands as more of the available supply is utilized, especially for agricultural purposes. Stakeholder respondents indicate climate change exacerbates this problem because of its impact on water sources, namely changes in snowpack levels, spring runoff timing, and aquifer depletion. At the forefront of the water distribution challenges are endangered and listed species, whose protection and management are limited by water supply. Habitat degradation and preservation, invasive species control and prevention, and funding were also commonly mentioned concerns.

Respondents cited a number of data gaps that currently impede their organizations' ability to use remote sensing data to inform decisions. The most frequently mentioned of those was related to the temporal frequency of satellite imagery, particularly Landsat and NAIP imagery, and the time gaps in usable imagery due to obstacles like cloud cover and smoke. A desire for higher temporal frequency availability of thermal band data was also mentioned. Image resolution was also a common concern, particularly the need for high-resolution imagery that is usable on a local scale. Data latency and specificity were common concerns, as were the need for groundwater/aquifer data, water quality, and bathymetric data. A number of respondents indicated a need for more water related prediction data, like precipitation recharge cycles, warming cycles, large storm events, and drought prediction.

The size of an organization, by staff size and geographic extent, was a major determining factor in its approach to the adoption of new data sets, information, and models. Large agencies tend to have divisions specialized in data collection, vetting, and dispersal. State agencies typically have a limited number of staff whose primary responsibility is to acquire, vet, process, and disseminate new data sets. They often depend on meetings, technical groups, and partner agencies to supply desired data. Smaller stakeholders such as private companies often identify a need for a specific project, then research internally or contract out for services. Many stakeholders expressed a lack of capacity, staff resources, and time for post-processing of data. Some stakeholders also suggested the ability for data to be both downloadable and available as a service without the need for post-processing.

The approaches for accepting new data sets were highly variable, but ultimately the most important considerations were whether the data provided a benefit at little or no cost, the amount of post-processing required, and whether the data were easy to use. A few of the stakeholders interviewed expressed they do not currently use remote sensing data in their current operations for reasons including resolution issues, excessive post-processing, and inapplicability of the data. Other barriers include data latency, cost, equipment, training, and technological concerns. The report also included an analysis of stakeholder organizations' openness and capability to adopt new data sets, information, and models. Many respondents indicated remote sensing information plays a vital role in their operations and decision-making processes.

Stakeholder organizations and representatives who participated in the interview process were invited to attend the Columbia River Basin Needs Assessment Workshop in Portland, Oregon in September 2019. A summary of the workshop, it's methodologies, and results is presented in the remaining sections of this report.

3. NEEDS ASSESSMENT WORKSHOP

Building on the interviews conducted in April and May of 2019 and subsequent written report, stakeholder organizations and representatives were invited to attend the Columbia River Basin Needs Assessment Workshop. The goal of the workshop was to further explore information gaps and needs that WWAO may be able to address. Once needs were identified, participants developed preliminary “use cases” describing the need and the policy or decision-making framework. These use cases provide critical insight for the next step of matching user needs with WWAO capabilities. A description of the use case development methodology is presented in Section 4. The results of the use case development process are presented in Section 5.

3.1. Workshop Format

The CRB Needs Assessment Workshop took place on September 11th and 12th, 2019 at the City Center Marriott in Portland, Oregon. There were twenty-seven stakeholder representatives, six NASA WWAO technical representatives, and four SPF workshop facilitators in attendance. Some of the stakeholder representatives were participants in the April and May interviews. Interviewees were also asked to extend the workshop invitation to colleagues who may wish to participate. A complete list of stakeholder attendees is presented in Table 3.1 below.

On the first day of the workshop stakeholder representatives were familiarized with WWAO, its mission, capabilities, and goals within the CRB. Stakeholder representatives were introduced to successful projects and partnerships resulting from a previous basin study. The first day concluded with a group brainstorming session to discuss the biggest water management challenges facing the CRB. A preliminary list of 54 water management challenges was formulated and categorized into four major categories: Agriculture, Water Quality, Water Supply, and Watershed Health.

On the workshop’s second day, attendees were assigned into work groups that each represented one of the four categories developed on day one. Each attendee’s assignment was guided by the basis of his or her work and expertise. Consideration was also given to the participants’ agencies/organizations so that each group contained a balance of perspectives representing different states, organizations, agency missions, and priorities.

Each group was tasked with selecting the three most important challenges facing the CRB within their assigned category and developing at least three “use cases.” A complete explanation of the use case methodology is described in the following section. Participants were encouraged to move between category groups to help facilitate cross pollination of ideas and perspectives. A total of fourteen use cases were developed through the needs assessment process. At the conclusion of the workshop, WWAO representatives encouraged participants to submit additional use cases if they felt additional needs existed that had not been addressed at the workshop. A number of use cases have since been forwarded to WWAO; which are described briefly in Section 4.5.

Table 3.1 – Needs Assessment Workshop Attendees

Organization	Name	Position
City of Portland *Bureau of Planning and Sustainability*	Ethan Brown	City Planner II - Environmental
Columbia River Inter-Tribal Fish Commission	Lauren Burns	Fishery Biologist
Idaho Department of Water Resources	Linda Davis	Water Resource Information Section Manager
National Oceanic and Atmospheric Administration *Northwest Fisheries Science Center*	Kevin Werner	Science and Research Director
	Chris Jordan	Research Fisheries Biologist
	Morgan Bond	Fishery Biologist
Oregon Department of Agriculture	Margaret Matter	Water Resource Specialist/Water Resources Program Lead
Oregon Department of Environmental Quality	Paula Calvert	Columbia River Coordinator
	Brian Fulfrost	GIS Specialist
Oregon Water Resources Department	Rachel LovellFord	Water Development Coordinator
	Benjamin Scandella	Groundwater Data Chief
	Ryan Andrews	Hydrologist
Portland State University *Department of Environmental Science and Management*	Kelly Gleason	Assistant Professor
University of Idaho *Department of Soil and Water Systems*	Jason Kelley	Assistant Professor
US Bureau of Land Management	Michael Brown	Oregon and Washington Water Resources and Soils Program Lead
	John Colby	Hydrologist
USDA Natural Resources Conservation Service	Melissa Webb	Hydrologist
	Gus Goodbody	Senior Hydrologist, Forecasting
US Geological Survey	Sylas Daughtrey	Hydrologist
	Terrence Conlon	Supervisory Hydrologist, Studies Chief
	Kristin Jaeger	Research Hydrologist
	Jonathan Haynes	Hydrologic Technician
Washington Department of Ecology	Jeff Marti	Water Resources Planner
Washington Department of Fish and Wildlife	Kiza Gates	Water Science Lead
Washington State Conservation Commission	Jon Culp	Program Manager
Washington State Department of Agriculture *Natural Resource Assessment Group*	Gary Bahr	Natural Resource Manager
Washington State University *Center for Sustaining Agriculture & Natural Resources*	Kirti Rajagopalan	Assistant Professor

Table 3.2 – Needs Assessment Workshop Facilitators

Organization	Name	Position
NASA WWAO	Amber Jenkins	Project Implementation and Strategic Initiatives Lead
	Bailing Li	Research Associate NASA GSFC
	Forrest Melton	Program Scientist
	Indrani Graczyk	Program Manager
	Karen Yuen	Science Data Applications Lead
	Stephanie Granger	Program Strategist
SPF Water Engineering	Grae Harper	Project Engineer
	Heather Neace	Associate Hydrologist
	Marci Pape	Project Engineer
	Ron Manning	Project Manager

3.2. Use Case Methodology

WWAO selected the Use Case Methodology as the means of describing CRB water resource decision making needs from an expert perspective. The use cases are intended for assessing water resources needs with enough detail to develop projects and communicate those needs to NASA WWAO team members. Use cases are short examinations of how decision makers use data to support water management and to identify gaps that could be filled using Earth Observations. Use cases are used to systematically analyze data needs for decision making and communicate those needs to technical developers. Use cases are intended to answer the questions of *who* needs *what data* in *what form* to make *what decisions* [3]. Table 3.3 presents the use case development template developed to guide stakeholders in expressing use case features.

3.3. Use Case Development Process

To assist the category groups in the use case development process, WWAO provided a list of questions and a use case template to fill out during breakout group discussions. Each group considered the many needs related to that category and debated the relative importance of each need. With varying approaches, each group settled on three to four needs that were either commonly felt across many stakeholder organizations or were of highest importance. Using the use case development questions and the use case template, each group came to a consensus in defining each need, obstacles to meeting that need, and partnering potential. The process was repeated for each use case until each group either met their minimum requirement of three use cases or used up their allotted breakout discussion time.

Table 3.3 – Modified Use Case Template

Use Case Element	Description
Current State	Current decision-making process and the data and models used to support decision making, or the water management challenge where lack of information is precluding progress.
Desired Result	Desired improvements to the decision-making process or the water management challenge.
Need/Gap/Objective	The information needed to achieve the desired result.
Description/Decision Context	The decision to be made, how it is made, and who makes the decision, including information about what data are used to inform the decision-making process and who is currently responsible for producing and/or interpreting the data.
Participants	The primary participants who are impacted by this need.
Workflow	The flow of information from a set of inputs to models to outputs that are used to make the decision.
Priority (MI, VI, I)	Provide a rough estimate of the priority of the need as MI (Most Important), VI (Very Important), or I (Important). Include the rationale for prioritization, if possible.
Obstacles to address the need?	Obstacles to addressing the need (participation, administrative boundaries, funding, etc.).
Data Sources	Describe potential sources of information that are aligned with the data characteristics defined above.
Data Characteristics	Describe the required characteristics of the data needed to improve the decision. Include necessary modifications to existing models.
Partner Potential?	Identify the primary organization that would partner with WWAO to develop/implement a potential project to address the need, including name(s) and contact information.

4. USE CASES

Fourteen use cases were developed by breakout groups at the workshop and are presented in Table 4.1 below. Four use cases were developed for the Water Supply and Watershed Health categories and three use cases were developed for the Agriculture and Water Quality categories.

Table 4.1 – Use Cases by Category

Agriculture	Water Quality	Water Supply	Watershed Health
Crop Mapping	Cyanobacteria	Evapotranspiration	Habitat Management
Evapotranspiration/ Consumptive Use	Stream Temperature	Groundwater Recharge & Storage	Land Use & Land Cover
Irrigation Management & Scheduling	Turbidity	Snow Water Equivalent	Surface and Groundwater Interaction
		Streamflow Monitoring	Stream Temperature Dynamics

The final fourteen use cases are discussed in detail below. Included for each use case is a completed use case table and a summary of the use case development process, including important themes that were discussed by breakout groups.

4.1. Agriculture Use Cases

4.1.1. Crop Mapping

Several regulatory decisions related to water management are made using crop mapping data, which includes annual or seasonal field-scale information on crop type and irrigation status. Water managers rely heavily on crop mapping data to support water rights administration, compliance, and beneficial use. Crop mapping data are used to support water demand planning and forecasting as well as drought impact response. Currently available crop mapping data are not consistent across the CRB due to funding disparities between states. Crop mapping data are often provided at resolutions too large to meet individual users' needs. Remotely sensed data on crop type and irrigation status at the scale of individual agricultural fields would alleviate the need for tremendous staff resources associated with windshield surveys. Table 4.2 presents a summary of the Crop Mapping use case developed at the workshop.

Table 4.2 – Crop Mapping

Use Case Element	Description
Current State	Missing consistent crop data to support allocation and curtailment decisions, groundwater models, and water demand forecasting.
Desired Result	Consistent data to support allocation and curtailment decisions, groundwater modeling, and water demand forecasting.
Need/Gap/Objective	Need consistent field-scale information on irrigation status and type, crop type, single/double cropping without excessive staff time. Need seasonal maps of irrigation status.
Description/Decision Context	Water managers need crop mapping for regulatory and planning purposes.
Participants	Main Decision Maker: Agency staff and water masters
	Additional Participants: Agency field staff
Workflow	None specified.
Priority (MI, VI, I)	MI: Idaho, Washington VI: Oregon, USGS
Obstacles to address the need?	Concerns about privacy within the agricultural community.
Data Sources	NRCS, WA Dept. of Ag, USDA NASS Cropland Data Layer (CDL), windshield surveys, extension services, USGS.
Data Characteristics	Field scale (30m), twice per year, known accuracy; latency: within 3 months of water year. Formats: Web-based, downloadable shapefiles
Partner Potential	WA, OR, & ID Depts. of Ag, NRCS, USDA NASS, WSU, OWRD, UW EScience Institute/Data Science Center, Farmers Conservation Alliance, Freshwater Trust, NRCS resource conservation districts (RCDs), irrigation districts, ID and WA soil conservation commissions.

Crop mapping is an important tool in the administration of water rights, from the evaluation of water right transfer applications to the assessment of beneficial use. This is especially true for beneficial use and forfeiture analysis. State agencies use crop mapping data to determine if water users are abiding by collaborative agreements and to determine when prior appropriation is necessary.

Crop mapping data are useful to regulatory agencies, irrigation districts, and commodity groups in times of curtailment to support informed, strategic decisions aimed at reducing the impacts of cutbacks in irrigation water supply. It is also useful for water banking and water trading in times of water supply deficit. For water use planning and forecasting, the most widely utilized crop mapping data include crop status, including the number of cuttings within each season, crop types, irrigation type, and double cropping.

Commodity groups also have a desire for crop mapping data. Commodity groups use crop mapping data to monitor varieties and acres of particular crops, like grapes. This information is useful as water needs and consumption may vary by crop variety.

Crop mapping data vary greatly by state. Washington has been gathering crop mapping information for over ten years with four staff members collecting field-level crop information and irrigation type through “windshield surveys.” Windshield surveys produce valuable results but are time-consuming and expensive. Oregon and Idaho have not made resources available to duplicate Washington’s field survey efforts, resulting in incomplete information on watershed sub-basins that cross state boundaries, such as the Walla Walla.

Stakeholder representatives indicated that CRB crop mapping data have inconsistent availability, scale, and accuracy. Consistent field-scale information is needed on irrigation status and type, crop type, double-cropping, and rotation to reduce the need for windshield surveys and hand digitization. Also, a process to identify targeted regions for windshield survey and manual mapping would be helpful. NRCS has crop data, but availability is somewhat dependent on staff resources. There are limitations in crop mapping data availability due to the Farm Bill, but since NRCS is a third party, they do have summarized data at acceptable resolution for some purposes. Some crop mapping data producers only provide data on a county-level scale.

Another potential use of remote sensing data could be related to crop coverage, and fallowed land in particular, as it relates to flooding and erosion events. Of particular interest is the ability to identify the potential benefits of different cropping systems in reducing erosion and flooding events.

Data characteristics for remotely sensed cropping data vary by needs. From a regulatory perspective, the collection of cropping data once per season is sufficient to make beneficial use determinations. However, to make an accurate estimate of seasonal water use for planning purposes, it is important to capture cropping data more than once per season. For most uses, field-scale spatial resolution is sufficient, but the ability to identify sub-field variability would be helpful for making determinations such as irrigation or non-irrigation of pivot corners.

Obstacles to addressing the need for crop mapping data include concerns about privacy within the agricultural community. Those concerns must be addressed through outreach and engagement of state Farm Bureaus. A stakeholder representative suggested encouraging participation by emphasizing the need to collect quantitative data to support decisions that do not lead to increased regulation. Rather, crop mapping data collection should be contextualized as pre-regulatory baseline data collection. A number of potential partners could play a role in gaining acceptance within the agricultural community.

Stakeholder representatives indicated crop mapping was important because of the integral role agriculture plays in water management. Accurate crop mapping will support informed decisions on water allocation, water rights, groundwater modeling, and more. However, collaboration with the agricultural community may play an important role in future crop mapping project success.

4.1.2. Evapotranspiration/Consumptive Use

Accurate estimates of evapotranspiration (ET) play an important role in state, federal, and local agency operations. ET data are critical in the administration of water rights, allocation of water, development of water markets and banks, and the preservation of adequate water supplies through planning and forecasting. Currently, there are a number of different methods and data sets used across the CRB. Stakeholders expressed a need for consistent, authoritative data sets and methods of determining ET that are from a trusted source and are agreed upon by users. Table 4.3 below presents a summary of the ET use case developed at the workshop.

On a small scale, state water resource agencies use ET when administrating individual water rights. For example, determination of ET is necessary on a field scale for the analysis of water right transfers involving changes in the nature of use and for water right applications involving pond and reservoir storage. On a larger scale, ET is used in planning and forecasting water budgets for entire sub-basins. ET data are important in developing mechanisms for coping with drought and the prevention of over-allocation.

Table 4.3 – Evapotranspiration/Consumptive Use

Use Case Element	Description
Current State	Lack of consistent, authoritative method and data for determining ET.
Desired Result	Authoritative, consistent, legally defensible methods and data for determining ET.
Need/Gap/Objective	Stakeholders need agreed upon, authoritative data and methods that are consistent across large geographies.
Description/Decision Context	ET data are used to administer water rights, quantify water use, support the development of water markets, and in planning and water use forecasting.
Participants	Main Decision Maker: Federal/state/local agencies and community groups
	Additional Participants: Commodity groups and commercial vendors
Workflow	None specified.
Priority (MI, VI, I)	MI – Oregon, Washington VI – Idaho, USGS
Obstacles to address the need?	Concerns from agricultural sector about data privacy and constraints on water.
Data Sources	METRIC, gridMET, Cuenca, et al. [4], ET-Demands, Pumping records, SSEBop, AgriMet, AgWeatherNet, Eddy Covariance, Biophysical models, and ETIdaho
Data Characteristics	Field scale (1-100m), sub-monthly, +/-10% accuracy, 2 to 12-week latency Formats: Web data services, Web-based maps, ESRI compatible
Partner Potential	OWRD, IDWR, USGS, USACE, WA Dept of Ecology, Office of the Columbia Basin; BPA, WSU, Ag Weather Network, DRI, commodity groups, and commercial vendors

ET is used for water accounting purposes, particularly in agreements where specific water use amounts have been agreed upon. For example, the Walla Walla Basin crosses state boundaries, so there are two states involved in developing a water model and maintaining a strategic management plan. In Idaho, there is an agreement between groundwater and surface water users limiting the total number of diversions by groundwater users within the Eastern Snake Plain Aquifer. The Columbia River Treaty is an interstate agreement that involves the U.S., states, Canada, tribal governments, BPA, and others and is under continuous negotiation.

Stakeholder representatives expressed concern about ET data accuracy. For example, it is difficult to measure the portion of ET that can be attributed to irrigation, rather than other sources such as precipitation and sub-irrigation. This is important in establishing an accurate representation of water demand for water budgeting purposes.

A major challenge for water managers is the current methodology for estimating ET. Different states, and even different agencies within one state, use different methodologies. Some of these methodologies are outdated. For instance, OWRD is currently updating their water availability modeling, which is based on an old method for estimating ET. Decision makers would greatly benefit from a framework for agreeing on methods for measuring and reporting ET. Because of the regulatory nature of water management decisions, ET data collection methods must be legally defensible. A collaborative agreement on methodology would result in reduced conflict over water rights and water use. NASA is seen as a source of authoritative, science-based information and their involvement would lend a great deal of legitimacy to the ET data collection process.

Consistent ET estimates that cover the CRB are necessary for water budgeting and would help alleviate problems associated with fragmented ET data collection methods across state lines. Streamlining the approach to basin ET estimates will also assist with cooperation of informed planning between regulatory agencies.

4.1.3. Irrigation Management & Scheduling

Data-driven irrigation management and scheduling is currently under-utilized within the CRB, even though advancements are continually being made. There are a number of reasons for this, most importantly the monetary expense and the necessary time commitment, as well as the complicated nature of the data and methods. As a result, the most frequent users of data-driven management tools are large corporate agricultural entities. Irrigation management tools will likely be more widely accepted by farmers and operators in the CRB if the information is provided in an accurate and easily accessible way. Table 4.4 below presents a summary of the Irrigation Management and Scheduling use case developed at the workshop.

Some of the goals for adoption of remote-sensing crop management products and technologies include more efficient use and effective management of water, reduced leaching and runoff, increased quality control, increased crop yields, and less water, electricity, and fertilizer use. Studies have shown that the implementation of irrigation scheduling and management is resulting in greater yields in some varieties of potatoes. The same has been true of wheat yields in drought limited conditions, where irrigation timing proved to be essential. Irrigation scheduling may become increasingly important, too, as water supply becomes more limited and the window of water availability becomes smaller.

The primary obstacles with the adoption of data-driven irrigation management and scheduling methods are the necessary investments in both money and time. The acceptance of these technologies is highly dependent on whether farmers can be convinced that the data quality is better than what they currently use. For smaller farm operations, the bulk of the responsibility in educating operators about the benefits of data-driven management tools currently lies with extension agents and crop consultants.

In some cases, products are being purchased, but then under-utilized. Proximal measurement equipment like field based NDBI sensors have been adopted, but the benefits are unclear, and the equipment is often not well-maintained. In general, water managers are finding that there is an interest, but lack of faith in these types of tools.

Implementation of new management tools and methods is also highly dependent on the training that is made available to operators. They have an interest in learning new methods, but they have a very limited amount of time to learn how to use the tools. Additionally, those tools must be easy for them to access. A workshop participant gave an example in which the Idaho AgriMet coordinator had indicated that there was an increase of as much as 70 percent in website visits and the use of AgriMet data after operators began receiving a daily e-mail containing daily ET information. Ideally, the data that operators need should be specific to their location, in a format that they can make a meaningful interpretation, and available in a single product. WSU has created a tool called the Irrigation Scheduler tool, which is available as a phone app and uses data inputs such as crop, irrigation system capacity, etc., as well as ET from the nearest weather station, and calculates your deficit.

One participant expressed that consumers of remotely sensed crop management data could also participate in the collection and sharing of data, with the understanding that theirs is not sufficient for basin-wide mapping, but can be useful as site-specific data to help support and validate the remotely sensed data.

This use case was discussed as a way to make more detailed data on crop management available to all farmers. If this project was implemented this could improve overall knowledge of the current conditions, ideally in an easily accessible format such as a mobile phone application. Collaboration on this project would benefit both the larger scientific community for water budgeting, as well as the individual farmers.

Table 4.4 – Irrigation Management

Use Case Element	Description
Current State	Data-driven irrigation scheduling not fully adopted or widespread.
Desired Result	Increased efficiency in water and nutrient management; improved crop yields.
Need/Gap/Objective	Accurate and easily accessible information on ET, root zone soil moisture, crop canopy development, and weather conditions.
Description/Decision Context	Localized ET, crop, soil moisture, and weather data are used to make decisions regarding irrigation timing and amount.
Participants	Main Decision Maker: Producer (farmer) and irrigator
	Additional Participants: Crop consultants, extension services, and irrigation districts
Workflow	Data are received and used to develop an irrigation schedule.
Priority (MI, VI, I)	VI for all (MI for agriculture producers in the CRB)
Obstacles to address the need?	Engagement with producers.
Data Sources	Ag Weather Net, WSU's Irrigation Scheduler, NRCS, soil moisture sensors, hand meters, reference ET, and Leaf Water Potential measurements.
Data Characteristics	Field-scale, daily, +/-15% or better accuracy, and <24-hour latency. Formats: Mobile apps or email
Partner Potential	Agriculture extension services, land grant universities, USDA ARS, Farmers Conservation Alliance, conservation districts, commodity groups, Northwest Energy Efficiency Alliance, BPA, and power companies.

4.2. Water Quality Use Cases

4.2.1. Cyanobacteria

Currently the Cyanobacteria Assessment Network (CyAN) program monitors large drinking water systems to detect algal blooms in freshwater systems [5]. It was discussed that while this program provides a great comprehensive view of cyanobacteria algal blooms, it does not cover small bodies of water or provide an early warning system. The application is available on Androids, but not for iPhones, so accessibility is also an issue. This use case was built upon the idea that both monitoring of smaller reservoirs and lakes and development of an early warning system are needed to prevent potential health issues.

The project would need to collaborate with EPA, the main actor in the creation and maintenance of the CyAN application. Data coverage and resolution would be increased to monitor smaller bodies of water, using the current technologies in place. It was discussed that a prediction system, which could compare current temperatures and other water conditions to yearly trends, would be ideal to integrate into the application. The prediction system could be used as the early warning system; when conditions suited for algal blooms are found, the early warning could be released. The data obtained for the project would need to be processed for the CyAN app daily in order to deliver same day warnings.

The other participants would include NASA, NOAA, and USGS, who are all currently working on the CyAN project. Potential partners for the project would be State Departments of Environmental Quality, specifically ODEQ who has interest in monitoring cyanobacteria on a small scale since they play a significant role in the protection of drinking water in Oregon.

Stakeholders assigned this use case a priority level of ‘Important’ because it does not broadly affect the basin, but rather is an issue in specific areas. A potential barrier to the success of the project would be the lack of funding, adequate data, and manpower to monitor at a smaller scale. The app would need to be expanded to allow for iPhone access so all concerned parties would be able to view the conditions.

The use case was developed to further improve the CyAN program, which could be adjusted for early warning systems and more open access to information. Data coverage and resolution could be increased to protect those most vulnerable to algal blooms, such as small children and dogs, in small reservoirs or lakes. Improvement of the application would only require an expansion of the current project.

Table 4.5 – Cyanobacteria

Use Case Element	Description
Current State	The CyAN project does not cover smaller bodies of water.
Desired Result	CyAN coverage of small bodies of water.
Need/Gap/Objective	(1) Scale down CyAN to cover smaller bodies of water and (2) develop and early warning system for drinking water systems.
Description/Decision Context	Currently CyAN is large scale and covers large bodies of water, but contains no early warning system.
Participants	Main Decision Maker: EPA
	Additional Participants: NASA, NOAA, and USGS
Workflow	None Specified.
Priority (MI, VI, I)	I - Affects specific areas of the basin.
Obstacles to address the need?	Lack of funding, adequate data, and manpower.
Data Sources	Same as CyAN, but scaled down.
Data Characteristics	Ability to work on IOS and Android. Formats: Phone application
Partner Potential	State Departments of Environmental Quality, specifically ODEQ

4.2.2. Stream Temperature

The water management community in the CRB has been using stream temperature models for years to successfully demonstrate the current water temperature of the Columbia River and its tributaries. According to water management stakeholders at the workshop, what is lacking are comprehensive modeling capabilities that can demonstrate what is causing changes in water temperature. Stakeholders expressed concern that without these capabilities, it is difficult to develop projects that reverse water temperature impacts. Table 4.6 presents a summary of the Stream Temperature use case developed at the workshop.

Table 4.6 – Stream Temperature

Use Case Element	Description
Current State	Temperature impaired waters.
Desired Result	Non-temperature impaired waters.
Need/Gap/Objective	Water management stakeholders do not possess large enough models to show why waters are temperature impaired.
Description/Decision Context	Water management stakeholders currently have small, data intensive models that can predict why waters are being impaired, but they cannot be scaled up without significant effort.
Participants	Main Decision Maker: ODEQ
	Additional Participants: WA and ID DEQ, Fish/Wildlife, Natural Resources, EPA, NOAA, USGS, USFW, USACE, BPA, ID Power, BC Hydro, and Tribal Entities
Workflow	None specified.
Priority (MI, VI, I)	MI – water temperature impacts cut across all other categories as an impact or a contributing factor and the magnitude of its impacts are significant on the environment.
Obstacles to address the need?	Comprehensive approach – individual actors put forth effort, but a comprehensive approach is required.
Data Sources	Individual gauges, systems of gauges.
Data Characteristics	None specified.
Partner Potential	See "Additional Participants" above.

Many water management stakeholders at the workshop have responsibilities that include monitoring temperature of water bodies in their jurisdiction. The objectives and goals motivating monitoring water temperature are as diverse as the number and types of water bodies being monitored and the entities in responsible charge for carrying out the task. For example, the Oregon Department of Environmental Quality may monitor water temperature to ensure compliance with Total Maximum Daily Loads (TMDL), the calculated pollutant amount that a waterbody can receive and still meet Oregon water quality standards, while Ducks Unlimited may be monitoring water temperatures to determine which stretches of river may benefit the most from environmental remediation activities [6].

In both cases mentioned above, the entities utilizing temperature data are not installing or maintaining the stream temperature monitoring devices. Instead, these entities are responsible for processing temperature data, either analytically or with modeling software, to accomplish their monitoring goals. The stakeholders that install and maintain stream temperature monitoring infrastructure may have different or diverging interests for monitoring stream temperature than other stakeholders in their jurisdiction. Because of this, stream temperature monitoring devices may not be placed in the most ideal locations to accomplish the objectives of all stakeholders. Stakeholders at the workshop expressed interest in a comprehensive approach to stream temperature monitoring to help solve this challenge.

Funding and stream access play important roles in determining where monitoring devices are installed. If a stakeholder cannot access a stream because of private land ownership or geographic constraints, stretches of river may go unmonitored even though they could prove vital to accomplishing stream temperature monitoring goals or objectives. Similarly, installing and maintaining stream temperature monitoring devices can be expensive. It is often the case that monitoring devices are temperately installed and maintained to accomplish a specific task and then removed due to funding constraints. Stakeholders at the workshop stressed the importance of moving towards a remotely sensed stream temperature monitoring system to alleviate funding and stream access challenges. However, many stakeholders expressed that the resolution of existing remotely sensed stream temperature data are not high enough to capture smaller streams or rivers.

Many times, entities that share common stream temperature monitoring goals and objectives but are located in separate jurisdictions do not (and often times cannot) work together to identify common contributing factors to stream temperature impacts. For example, Departments of Environmental Quality from Oregon and Washington may have the same stream temperature monitoring goal, ensuring TMDL compliance, but do not work together to identify major sources of stream temperature loading. The concern here, according to stakeholders at the workshop, is that stream temperature impacts vary temporally - the further downstream, the larger the impact on the ecosystem. Sources of temperature loading on a stream that originate in one jurisdiction may have the greatest impact on the ecosystem in a downstream ecosystem.

In all the cases mentioned above, stakeholders at the workshop stressed the importance of a comprehensive approach to solving stream temperature challenges in the CRB. A comprehensive approach may offer a more complete picture of the impacts of stream temperature on ecosystems in the CRB. Additionally, a comprehensive approach may allow for resource (financial or otherwise) sharing opportunities that would allow stakeholders to scale up existing data processing and modeling activities and demonstrate what is causing changes in water temperature and therefore develop projects to reverse stream temperature impacts.

4.2.3. Turbidity

Water stakeholders in the CRB have significant interest in the sediment load within the Columbia River. Turbidity and suspended particles can be used to calculate the sediment load. Currently the suspended load is being determined by turbidity meters and Acoustic Doppler Velocity Meters (ADVM), which only cover a small width of the river. The ADVM measurements are done a few times a year, but the need for understanding sediment load and total suspended solids (TSS) is important for mercury budgets, dune formation, fish habitat, agriculture, and forestry. An increased number of ADVMs and turbidity meters throughout the Columbia would improve the accuracy of the sediment load calculations. The improvement in temporal and spatial resolution could allow for a better understanding of weather events' effect on sediment loads.

Table 4.7 – Turbidity

Use Case Element	Description
Current State	Limited understanding of impacts of large hydrologic events on sediment loading.
Desired Result	A more accurate and larger scale understanding of sediment loading.
Need/Gap/Objective	Need to increase accuracy and scope of sediment loading models as well as how they relate to weather patterns.
Description/Decision Context	We have an area-specific understanding of sediment transport, but a regional or basin-wide scale would help address the problem in a comprehensive manor.
Participants	Main Decision Maker: USGS
	Additional Participants: Army Corps of Engineers
Workflow	None specified.
Priority (MI, VI, I)	Very important as systems change to understand cause and effect.
Obstacles to address the need?	Funding.
Data Sources	Turbidity, ADVM, and sediment sampling.
Data Characteristics	Coverage of the width of the Columbia.
Partner Potential	USACE, the Port of Portland, the Department of Ecology, DEQ

The project would require an increased number of turbidity meters and ADVMs to cover the width of the Columbia in several locations. A model could be built off the meters and correlated to weather patterns to have a greater understanding of the relationship between specific events and sediment load, which would assist in detecting areas for field measurements as well.

USGS would be the main decision maker as they currently monitor turbidity and suspended sediment in the Columbia. The USACE tracks sediment load for dredging purposes in the lower Columbia, so they would be an additional partner. The Port of Portland, Department of Ecology, and DEQ would be potential partners as their area of work is directly affected by sediment load. The priority level was assigned as 'Very Important' because over time being able to predict local weather patterns and sediment load response will help our understanding of how to mitigate negative environmental effects. The major obstacle for the project was identified as funding.

This was developed as a use case to increase the accuracy and understanding of the sediment load in the Columbia River. Many industries and agencies are affected by changes in sediment load and would benefit from drawing ties between weather patterns and the local sediment response.

4.3. Water Supply Use Cases

4.3.1. Evapotranspiration

Stakeholders within the CRB are very reliant on Evapotranspiration (ET) data for water rights administration and quantifying water availability, but some agencies use outdated and/or simplified methods that rely on crop use coefficients and irrigation regions to estimate the consumption. In some cases, there is not enough data coverage to fully implement consistent, accurate methods statewide. Implementation of new methodologies will also have to overcome current limitations with data storage and training, as well as gain general agency and stakeholder support. Table 4.8 below presents a summary of the Evapotranspiration/Consumptive Use use case developed at the workshop.

One of the obstacles to addressing the need for large extent remotely sensed ET data and methods is that Oregon does not necessarily have accurate estimates of field boundaries, in that the place of use authorized by a particular water right does not always accurately represent the actual acreage that is being irrigated. Currently, the process of mapping field boundaries and calculating ET data is extremely resource intensive, and using remote sensing to do it is especially challenging in the western part of the state. This information, along with Cuenca irrigation regions, is an input in the existing model used for determining water availability [4]. Improving accuracy of this model input will increase the precision of both small and large-scale estimates of consumption.

The Cuenca crop use coefficients that are currently used in Oregon's water availability model are based on regional estimates [4]. Remotely sensed ET data with field-scale accuracy and statewide coverage would be a tremendous asset in improving in the accuracy of water availability modeling.

Table 4.8 – Evapotranspiration

Use Case Element	Description
Current State	Currently crop use coefficients and coarse field boundaries are used to estimate ET and consumptive use.
Desired Result	Field scale ET, statewide coverage, delineated field boundaries, and better quantification water availability.
Need/Gap/Objective	Parameterization of ET data, field boundaries, net irrigation requirement, and climatological data.
Description/Decision Context	Stakeholders rely on ET to estimate consumptive use in order to derive water availability.
Participants	Main Decision Maker: Oregon Water Resources Department
	Additional Participants: DRI
Workflow	Water right place of use and crop coefficients used to estimate consumption and use in water availability quantification.
Priority (MI, VI, I)	OWRD: MI USGS: I
Obstacles to address the need?	Training, agency and stakeholder buy-in, and data storage.
Data Sources	Crop type, Cuenca coefficients based on location, and water right place of use.
Data Characteristics	30-m spatial resolution, weekly to monthly temporal resolution and latency Formats: Raster
Partner Potential	OWRD, NRCS, USBR, and USDA

One opinion expressed in the workshop was that good ET data already exist, but it may be more important at this point to make the existing product more useable and accessible, and expand its coverage area. This use case was developed to address the current lack of cohesive coverage and accuracy of ET estimates throughout Oregon. Improvement upon current techniques could assist Oregon regulatory agencies to better account for water rights and in consumptive use planning.

4.3.2. Groundwater Recharge & Storage

Groundwater estimates are important to water stakeholders throughout the CRB. Understanding of the under-ground availability is key to understanding the basin hydrology. Currently groundwater is approximated throughout Oregon based on USGS groundwater monitoring stations and by the paper ‘Estimated Existing and Potential Ground-Water Storage in Major Drainage Basins in Oregon’ by J.H. Robison in 1968 which uses the principle recharge=discharge to estimate groundwater storage [7]. It was mentioned that NASA’s Gravity Recovery and Climate Experiment (GRACE) data could be used to assist with estimates, but currently are not available in high enough resolution to be able to use at the desired scale. There is a great need for improved estimates for resource management and prioritizing basin studies.

The project would need to address the lack of high-quality estimates throughout the basin. The main decision maker would be OWRD, since they are heavily involved in groundwater monitoring. OWRD staff currently work with USGS on collaborative basin studies, so USGS would be an additional participant. NRCS was determined to be another participant, while potential partners could include WDEQ and IDWR.

For this project, necessary data would include higher resolution GRACE data, groundwater levels from the National Ground-Water Monitoring Network (NGWMN), and hydrographs for discharge. This data would need to be at a basin scale of less than 30 km with a 2 cm resolution. Measurements would best be taken in March to obtain discharge data from basin boundaries. It was discussed that information would be best formatted in rasters.

Groundwater estimation is in need of an updated estimation method. A more accurate technique than recharge equaling discharge, from the Robinson 1968 paper, is needed to improve groundwater management and the understanding of the hydrology within the CRB.

Table 4.9 – Groundwater Recharge & Storage

Use Case Element	Description
Current State	High-quality estimates of GW recharge are available in few basins in Oregon.
Desired Result	High-quality estimates of GW recharge in Oregon's surficial & layered aquifers.
Need/Gap/Objective	High-quality estimates of GW recharge are not widely available at the basin scale in Oregon.
Description/Decision Context	Reconnaissance-level estimates of GW recharge are critical components of resource management.
Participants	Main Decision Maker: OWRD
	Additional Participants: USGS and NRCS
Workflow	Recharge is estimated as part of detailed, basin-scale studies.
Priority (MI, VI, I)	MI
Obstacles to address the need?	Resolution of GRACE data, discharge at basin boundaries, and uncertainty in discharge estimation from hydrographs.
Data Sources	GRACE, GW levels (NGWMN), hydrographs (separate for discharge).
Data Characteristics	Basin-scale (<30 km), ~2 cm depth resolution, annual (in March). Format: Raster
Partner Potential	WDEQ and IDWR

4.3.3. Snow Water Equivalent

In the Pacific Northwest, 50 to 70 percent of the seasonal water comes from snow; in essence, the mountain snowpack acts as a high mountain reservoir. We currently have no spatially distributed measurement method for determining how much water is in that snow, the snow water equivalent (SWE). Currently, there are several highly calibrated statistical and process-based water resource modeling methods that are good at predicting flow downstream, but these mathematical models do not directly measure the total amount of water that is stored in the snow across an upstream watershed area at any given time. Table 4.10 presents a summary of the Snow Water Equivalent use case developed at the workshop.

The primary current SWE data source in the western US is the SNOTEL network. SNOTEL sites are ground-based weather stations where SWE and other environmental parameters are directly measured. The SNOTEL system is a mountain climate monitoring network. Nevertheless, sites typically are installed below tree line due to snow drifting and/or wilderness area restrictions, so the highest elevations are often underrepresented. Additionally, though SNOTEL is a large network with over 850 sites, the spatial coverage of any ground-based network is inherently incomplete. Remotely sensed SWE data with full spatial coverage, high sampling frequency, moderate to high spatial resolution, and short latency would therefore be highly valuable.

Snow-covered area (SCA) data are available from satellite remote sensing such as those derived from MODIS, but procuring spatially high-resolution snow depth depth and density data is resource intensive, either requiring field measurements or cost prohibitive flights. One participant cited the cost of Airborne Snow Observatory (ASO) snow depth data for one 200 square kilometer basin at $250,000. For routine, ongoing, CRB-wide coverage, satellite observation platforms may be preferable.

Another point made in discussions was that SWE for wet snow is much more difficult to measure using remote sensing than dry snow, and much of the CRB could be described as having wet snow. The region is also a topographically complex region, which adds additional challenges.

Snow albedo data are also very important, and may be a more reachable short-term goal. Water availability is highly dependent on snowmelt, which is dependent on the energy in the snow. That energy is driven by the amount of sunlight, which in turn is driven by reflectivity.

An additional complication for mainstem CRB management is that it is an international basin with a discontinuity in SWE data coverage at the US-Canada border. The upper CRB is a modest percentage of the total basin area but has extremely large wintertime snowpacks, contributing disproportionately large runoff volumes. Independent SWE measurement programs exist in Canada. Additionally, the upper CRB has significant glacier melt contributions to river runoff, which are different from, and can complicate estimates of, snowmelt contributions.

In summary, SWE was determined to be an important dataset because the water supply is reliant on snowmelt, but spatially complete SWE data are not available across the CRB. Without that information, the accuracy of water supply predictions is limited. A more accurate and comprehensive SWE dataset or model for the CRB would assist in improved understanding of water storage and would be of interest to all water stakeholders in the region.

Finally, it is important to note that ground-based point observations of climate and snow (e.g., SNOTEL) are required for creating or ground-truthing gridded SWE datasets. Consequently, spatially high-resolution remotely sensed or modeled snow products will not replace SNOTEL or similar monitoring networks, and in fact will only increase the need for such ground-based sites.

Table 4.10 – Snow Water Equivalent

Use Case Element	Description
Current State	Extensive spatial point measurements but few spatially distributed data products exist for SWE.
Desired Result	Improved and spatially distributed SWE measurement, improved albedo measurements.
Need/Gap/Objective	SNOTEL and other networks of ground-based point observation locations do not fully capture spatial heterogeneity across the landscape, reducing accuracy of basin-wide SWE estimates.
Description/Decision Context	Used in streamflow forecasting, reservoir operations, water supply planning, infrastructure planning, climate change assessment.
Participants	Main Decision Maker: NRCS, BPA, USACE, and USBR
	Additional Participants: Power companies
Workflow	None specified.
Priority (MI, VI, I)	MI
Obstacles to address the need?	Topography, trees, snow wetness, and resource intensive data collection.
Data Sources	NRCS, MODIS (NASA), BPA, and direct measurements.
Data Characteristics	Basin-wide extent, Spatial: 30-500m, Temporal: Daily to weekly, near real-time (latency).
Partner Potential	NRCS, BPA, USACE, and USBR.

4.3.4. Streamflow Monitoring

Hydrologists within the CRB rely on the USGS StreamStats and similar streamflow models to determine the amount of water in streams. The accuracy of the stream data for ungauged streams is low; it would be helpful to have a better sense of the amount of water in all streams. Information on the permanency and periodicity of a stream is important for groundwater rights, the timber industry, agriculture, forestry, grazing, reservoir operators, pesticide and fire-retardant application, and state regulatory agencies. Currently USGS has stream gauges in some streams, and regression models are used to predict flow for ungauged streams. This information can be accessed through their StreamStats application [8]. Other agencies such as NRCS, USBR, and USACE have stream flow models as well.

Since there are not gauges in every stream in the CRB, it is also uncertain whether water is actually present in some streams. It was discussed that in order to better predict stream conditions, a need exists for a model or data set with a binary system of confirming whether or not there is water present in the stream. Many regulatory decisions, such as grazing permits, riparian buffer widths, pesticide application, timber harvest, and water rights, are based on stream flow/no flow.

The suggested project would consist of the creation of a model in conjunction with the USGS streamflow gauge data. This model could include presence/absence of water, but relative magnitudes would be even more helpful. This would help obtain data on what streams are ephemeral or intermittent. The main decision makers would be OWRD, EPA, IDFG, BLM, IDEQ, and USFS. Since so many agencies have streamflow models, a number of partners would be involved. Additional participants would include IDWR, WDE, and WDNR. Partners would potentially be USGS, USACE, USBR, and NRCS.

Obstacles might include tree covered streams, complex topography, and technical challenges that would prevent remote sensing data from being usable. Required data sources for the project were identified as stream gauges, remote sensing to determine whether areas downstream of gauges are wet or dry, USGS streamflow data, and potentially other streamflow models. The desired data characteristics are stream flow periodicity, permanency, wet/dry indicator, and stream extents to better understand the system of surface water throughout the CRB.

The project would include many agencies and benefit a wide array of natural resource applications. Understanding the amount of water in streams at least to the extent of whether they are ephemeral or intermittent will have implications throughout the CRB. The potential merging of streamflow models with additional remote sensing data could help improve the network of available streamflow data.

Table 4.11 – Streamflow Monitoring

Use Case Element	Description
Current State	Not all streams in the CRB are monitored, these ungauged streams are based on regression with a high uncertainty.
Desired Result	Surface water extent model with a wet/dry indicator.
Need/Gap/Objective	Knowing where water is present and for how long water is flowing in streams.
Description/Decision Context	Model of wet/dry indicator focused on headwaters and low-flow combined with gauged streamflow data.
Participants	Main Decision Maker: OWRD, EPA, IDFG, BLM, IDEQ, and USFS
	Additional Participants: IDWR, WDE, and WDNR
Workflow	None specified.
Priority (MI, VI, I)	MI
Obstacles to address the need?	Technical challenges, tree cover, and topography.
Data Sources	Gauges, remote sensing, and streamflow models (USGS, USBR, NRCS, and USACE).
Data Characteristics	Stream flow permanency, periodicity, wet/dry indicator, extent. Spatial resolution of 30 m, weekly updates from real time data. Formats: Raster/Vector
Partner Potential	USGS, USACE, USBR, and NRCS

4.4. Watershed Health Use Cases

4.4.1. Habitat Management

Habitat management was found to be a necessary part of prioritizing and protecting fish within the CRB. Stakeholders concerned with fish population, especially salmon, habitat restoration, and preservation have interest in providing streams with an increased amount of fresh water habitats. Hydropower dams can negatively impact fish populations; to mitigate this loss additional fresh water habitats must be provided. Currently salmon populations are declining, and the increase in fresh water habitat could increase the smolt to adult ratio (SAR). Habitat assessments are done to identify riverine habitats and prioritize locations lacking in available habitat. Habitat assessments were previously done through Columbia Habitat Monitoring Program (CHaMP), a project that is defunded. Habitats are now assessed through drone imagery and ground measurements which are compared to historical data from CHaMP, but a more comprehensive and rapid strategy is needed.

Table 4.12 – Habitat Management

Use Case Element	Description
Current State	X% of potential freshwater habitat supports salmon populations.
Desired Result	Y% of freshwater habitat is needed to meet biological objectives.
Need/Gap/Objective	An additional [Y-X] % of high-quality freshwater habitat is needed to meet the biological objective of smolt-to-adult return ratios (SARs) between 2-6%.
Description/Decision Context	Need for large-scale assessments of freshwater habitat to prioritize restoration.
Participants	Main Decision Maker: 1855 Treaty tribes (Yakama, Nez Perce, Umatilla, Warm Springs)
	Additional Participants: CRITFC, non-treaty tribes, NOAA, ODFW, WDFW
Workflow	Agree on desired habitat condition, assess condition, improve condition, and monitor.
Priority (MI, VI, I)	None specified.
Obstacles to address the need?	Quality and scale of remotely-sensed imagery; image and data processing and analysis time; linking analyses across spatial scales.
Data Sources	Ground-based assessments, drones, LiDAR, FLIR, and NLCD.
Data Characteristics	10 m resolution, twice a year, extensive throughout CRB, ability to combine with ground measurements. Formats: Web based
Partner Potential	BPA, USBR, Watershed Councils, Soil and Water Conservation Districts, Freshwater Trust, and OWEB.

The amount of fresh water habitat required to increase the SAR by 2-6% would be determined by a large-scale habitat assessment. For this project, the 1855 Treaty Tribes would be the main decision maker as they have significant interest in salmon population. Additional participants include CRITFC who works with the tribes to research fish population and health, Nontreaty Tribes, NOAA, WDFW, and ODFW who could provide additional data and support. Partners could include USBR, ODFW, Watershed Councils, Soil and Water Conservation Districts, Freshwater Trust, and OWEB.

Workflow would consist of collection of data for habitat assessment, prioritizing response, improving conditions, and monitoring the effects. Priority was not specified, but habitat assessment was discussed as an important step in restoring fish populations to previous extents. Data collection would include square meters of stream, temperature threshold, wetted surface area, pool habitat/density, and pieces of large wood. Spatial resolution would need to be at least 10-m to obtain meaningful data on instream habitats. The temporal resolution would need to be a couple times a year in order to capture summer low flows as well as habitat states during high flows. Habitat reassessment would then need to occur every ten years. The data would be most easily accessed and used as a downloadable raster on a web-based platform.

This project was identified as a use case because of the need to mitigate the effect of hydropower dams on the fish extent within the CRB. In order to efficiently target habitat restoration throughout the basin, large scale habitat assessment will need to be completed. Remote sensing capabilities may provide a solution to the current lack of a comprehensive and rapid habitat examination throughout the CRB.

4.4.2. Land Use & Land Cover

Land management decision makers throughout the CRB depend on evapotranspiration (ET) data to predict the effects of land use/cover change. There is not currently a model or cohesive set of data in the CRB to simulate different climatological effects on specific watersheds and streams. This is an important area that could be improved since these data apply to fire response to protect habitat or streamflow, salmon extent, water resources, and land management policies. There are several data sets used to analyze land cover/use throughout the CRB. The need for a model or cohesive data set with ET incorporated land use/cover was expressed by stakeholders in order to triage land management issues with a consistent strategy. Table 4.13 presents a summary of the land use/cover use case developed at the workshop.

Table 4.13 – Land Use & Land Cover

Use Case Element	Description
Current State	Lack of cohesive approach to categorizing land use and cover using ET data.
Desired Result	Prediction of water yield response to land use/cover change under different climatological scenarios.
Need/Gap/Objective	A model or data integrating ET with soils, geology, hydrography, precipitation information.
Description/Decision Context	Creation of a predictive model to determine how land use/cover affects water yield using ET.
Participants	Main Decision Maker: BLM
	Additional Participants: USFS and EPA VELMA program
Workflow	Coordination with EPA's VELMA model to improve upon or use as a base model.
Priority (MI, VI, I)	None Specified.
Obstacles to address the need?	Political setbacks.
Data Sources	NRCS soils data, USGS streamflow data, NASA Landsat data, OSU LandTrendr, and EPA VELMA model.
Data Characteristics	Spatial resolution of 3-30m, ability to run the model with daily updated precipitation data, ability to compare effects on individual streams. Formats: Web-based, downloadable raster, similar to EOSDIS
Partner Potential	USGS, EPA, ODFW, and other state agencies

Various agencies throughout the CRB play a role in post fire response and land management. The main partner decided at the workshop was BLM, who makes rapid response fire prioritization decisions. Other participants would include the USFS, who makes some fire intervention decisions, and the EPA, who currently runs the Visualizing Ecosystem Land Management Assessments (VELMA) model. VELMA simulates interactions between land and water in different scenarios to improve understanding of watershed response [9]. It was discussed that although this application is useful for water yield, this model is not parametrized for the CRB and does not take into consideration subsurface conditions or climatological conditions other than precipitation. Oregon State

University's LandTrendr model, which uses historical land data to show patterns in landscape change, was suggested to supply a broader viewpoint on the historical patterns in land management decisions. This model uses Landsat data to categorize changes in pixels over time with specific events such as fires or infestations [10]. This is a helpful addition from the perspective of land management, but it is currently limited by Landsat resolution, which was said to be too low for some land management applications. USGS was suggested as another participant to assist with flow data, as well as the Oregon Department of Fish and Wildlife, which could provide valuable inputs such as ET, biomass, and streamflow data. Other state agencies may be helpful in creating a cohesive set of data.

The workflow of this project would require NASA to assist in delivery of satellite ET data and coordination with the above-mentioned agencies. Priority was not specifically discussed as general importance but rather as a dire need for the rapid response fire prioritization which currently lacks efficiency and consistency. Improvement upon this process would help protect the most vulnerable habitats and communities. It was mentioned that the greatest obstacle might be political pushback preventing agencies from working together and prioritizing this project.

Data sources for this model or compiled data set would need to include soils data from the NRCS to take into account permeability and soil health, USGS streamflow data for individual stream flow conditions, ODFW biomass, streamflow, and ET data, NASA/USGS Landsat for topography and ET data, and the two models, VELMA and LandTrendr, which may be used as a foundation to improve upon or as additional data sets. These data would need to be at a high enough resolution that individual streams could be compared to prioritize fire response, within the range of 3-30 m resolution would be useable. This model would be used for rapid response, so the data would need to be readily available and the potential model would need to have a fast processing ability. It was discussed that a platform such as EOSDIS would be user friendly and accessible for data distribution and the preferred data format would be a raster.

This project was identified as a use case in order to bind together current resources to improve upon current land management data sets to make more informed decisions. This could have implications for communities, stream health, wildlife habitat, agriculture, development, and land management policies. The hope would be to streamline current practices among federal and state agencies to better coordinate land management decisions across all agencies.

4.4.3. Surface & Groundwater Interaction

For hydrologists in the CRB, there is a significant gap in understanding the surface and groundwater connection caused by human interference due to lack of high-resolution topography in the area. The limited topography data that currently exist throughout the CRB is characterized by its low resolution, inconsistent quality, boundaries, and season/time of collection. This leads to a vague understanding of the surface and groundwater interactions. Ground surveys are not feasible, so remote sensing is necessary to capture topography and causes of watershed disturbances. Private LiDAR flights or drones could be applied to this issue, but coordination of the data collection across administrative boundaries within the same season over the entire CRB is a large-scale project that would require a massive amount of funding. The goal of this project would be to build a tool or data set to identify areas of surface/ground water impairment for restoration.

Table 4.14 – Surface & Groundwater Interaction

Use Case Element	Description
Current State	Poor understanding of the magnitude of the surface and ground water connection.
Desired Result	Restoration of surface and ground water connection processes that have been disturbed by human land use at a basin-wide scale.
Need/Gap/Objective	Identification of impairments and source of land use change using high resolution topography data.
Description/Decision Context	Creation of a decision support tool to guide restoration of surface and ground water connection.
Participants	Main Decision Maker: NOAA
	Additional Participants: None specified.
Workflow	Collection of topography data and an application for confirmation or failure of the model in field.
Priority (MI, VI, I)	VI
Obstacles to address the need?	Administrative boundaries impacting a unified response.
Data Sources	NASA topography data, field confirmation, ET, ground water data, geology, soils, and land cover/use.
Data Characteristics	2 m grid, 10-50 cm vertical resolution at basin-wide or USGS Water Resources Region 17 wide scale. Formats: Raster.
Partner Potential	USFW, USFS, BLM, and Soils and Water Conservation Districts

The project would require a model or data set of high-resolution topography data that could be vetted through random field monitoring points to test accuracy. The extent would need to be basin wide and potentially all of USGS Water Resource Region 17, which includes watersheds along the coast, to restore CRB surface and groundwater connection. Land management agencies such as the USFS and BLM could assist with on-ground verification of model/data accuracy. For example, a field technician could investigate a brown pixel that was perceived as an incised channel and investigate to find out whether this is a point of disconnection between surface and ground water. Other partners would include USFW to monitor endangered species and Soil and Water Conservation Districts to monitor watershed health and use. Workflow would require collection of the topography data by NASA, processing of data into rasters, and combining data sources into compatible and consistent layers with characteristic categories.

As for temporal resolution, this project could be helpful with just one basin-wide coverage of the topography over the summer low flow when impairments would be most expressed to establish a baseline. Long term repetition of collecting basin-wide topography would be helpful to monitor progress/change. Stakeholders assigned this use case a priority level of 'Very Important' since impairment has large-scale trickle-down effects on water quality, temperature, and sediment transport. A potential obstacle to progress would be a lack of a unified response from many jurisdictions.

The data set would need to include topography for surface elevations, geology for sub surface information, soils for health and impervious conditions, existing ground water data for levels and temperature of subsurface water, land use/cover, and ET.

Updated topography was identified as an important data set for habitat restoration, land management, and overall watershed health. Though, it was noted that high resolution topography has much further reaching implications that would allow a more complete understanding of the water system throughout the CRB.

4.4.4. Stream Temperature Dynamics

Fishery scientists have a great need for accurate stream temperature data throughout the CRB. Finer resolution (1 km) temperature data for each stream reach could assist in the prediction of habitats within individual streams, potential emergence dates, fish size, life cycle modeling, and pre-spawn mortality. There are currently a few models/data used to analyze stream temperature. NOAA's Northwest Fisheries Science Center uses the USFS's NorWeST model which is based on thermal maximums taken in August to predict temperatures in different climate settings [11]. NASA currently produces MODIS data which could be used to assist in this issue, but it was mentioned there is not a comprehensive approach to monitoring stream temperatures since there are gaps in spatial resolution for headwater streams. This information could be used for both ecological and land management applications to help find the available habitat and source of issues within streams. This could further the understanding of how land use change affects individual streams and what precautions to take in order to protect instream habitats. Table 4.15 presents a summary of the temperature use case developed at the workshop.

Table 4.15 – Stream Temperature Dynamics

Use Case Element	Description
Current State	Need for higher spatial and temporal resolution temperature data for stream reaches throughout the CRB.
Desired Result	A daily averaged stream temperature model or data set for the main stem Columbia and all the reaches throughout the CRB.
Need/Gap/Objective	To have consistent data or a model which maps out daily averaged stream temperatures.
Description/Decision Context	Creation of a consistent set of temperature data throughout the CRB to assist in decisions for habitat and land management.
Participants	Main Decision Maker: NOAA Northwest Fisheries Science Center
	Additional Participants: Columbia River Inter-Tribal Fish Commission
Workflow	Working with NASA to obtain daily to weekly average satellite data on stream temperatures through data set or model.
Priority (MI, VI, I)	None specified.
Obstacles to address the need?	None specified.
Data Sources	USFS NorWeST Model, NASA MODIS data, and stream gauges.
Data Characteristics	Spatial resolution of 1 km, ability to access updated daily to weekly data, coverage of the entire CRB, accuracy within 2 degrees, preprocessed average temperatures for each reach. Formats: Web-based, downloadable raster like NHS or a model.
Partner Potential	CRITFC, USFS, QSI, and BLM.

Thermal maximum temperatures are currently the key indicators for stream temperature in the CRB. More accurate daily or weekly information is needed to understand the temperature changes throughout individual streams to fully understand available and potential fish habitat. NOAA's Northwest Fishery Science Center was discussed as being the potential main decision maker, as they conduct research to provide data for management decisions for ecosystems throughout the CRB. The Columbia River Inter-

Tribal Fish Commission would be an additional partner as they work with the Yakama, Warm Springs, Umatilla, and Nez Perce tribes to reverse fish decline in the CRB. Potential partners include USFS to work with their NorWeST model, QSI for heat source modeling, and BLM for additional data.

The workflow would require NASA's assistance in obtaining updated daily or weekly averaged streamflow data from the MODIS mission along with streamflow data from USGS and participation with the Forest Service to combine data sets or potentially build upon the NorWeST model. Priority was not specifically assigned, but it was made apparent that understanding temperature range within streams is inherent to identifying key fish habitat areas to protect them and make informed land management decisions.

Necessary data sources for the project were identified as NASA MODIS data to obtain remote temperature readings, stream gauges/temperature transducers to obtain real time instream temperature and to calibrate the model with NASA data, and the Forest Service NorWeST model. These data should be at a 1 km scale in order to observe specific tributaries within the CRB. Data would need to be processed and updated at least weekly to understand the current stream environments and monitor throughout the seasons. Accuracy of the temperature readings should be within 2 degrees to properly identify habitats. The preferred delivery method would be a web-based downloadable raster much like the National Hydrological Services (NHS).

This project was identified as a need to expand the current capabilities and available information on stream temperatures throughout the CRB. This would help improve knowledge of watershed health and instream habitats. With a comprehensive set of temperature data, prioritization of restoration and preservation of habitats could be done more efficiently.

4.5. Use Case Submissions

Stakeholders were encouraged to consider and discuss within their organizations the most important water management needs within the CRB and complete use case summaries for additional consideration if they felt there were important needs that had not been addressed. A number of additional use cases were submitted, either in person at the workshop or in the days following, as listed below.

- Spatially-refined estimates of groundwater recharge and storage changes
- Support in-season distribution and emergency management through forecasts
- Water planning support - past and future water use
- Statewide evapotranspiration for estimating consumptive use
- Freshwater habitat conditions for salmon

5. SUMMARY AND CONCLUSIONS

Through the collaborative efforts of stakeholder representatives, four groups representing Agriculture, Water Quality, Water Supply, and Watershed Health stakeholders formulated use cases. A total of fourteen use cases were developed during the Needs Assessment Workshop and have been summarized in this report. This effort provides the foundation for the next step in WWAO's project formulation process.

Each of the fifty-four water management needs identified in the early stages of the workshop were assigned to a major category and presented to its associated breakout group. That group then discussed their list of needs and selected those they felt were most important. Groups were not required to choose from their initial list, and their use case selections were not shared with the other groups until the developed use cases were presented. As a result, there are two repeated use cases. The Agriculture and Water Supply groups each developed use cases based on evapotranspiration (ET), and the Water Quality and Watershed Health groups each developed use cases based on temperature.

ET is a critical element in water management within the CRB. From an agricultural perspective, accurate estimation of ET is crucial to the proper administration of water rights for irrigation. Agricultural irrigation is a major consumptive use of water within the CRB, and different crops, climatological conditions, and irrigation methods can create enormous variability in agricultural ET values. On a larger scale, however, accurate estimates of ET are important for determining water availability throughout entire regions and for large-scale water use planning and forecasting. Thus, it is not surprising that ET was selected as a use case by two different groups. It is important to note that the focus of each group was slightly different. Whereas the Agriculture group was more concerned with how methods and data lacked consistency across the region, the Water Supply group was focused on Oregon's lack of framework for measuring and analyzing ET data.

It was suggested that the Stream Temperature use case from the Water Quality group and Temperature Dynamics use case from Watershed Health group should be combined. A reason for the grouping was that both use cases were centered around prioritization schemes. Another opinion in the group discussion was that temperature models are already available, but data are needed to add to current models for higher resolution so both use cases would align well together in the improvement of current models. The goal of both use cases was to have comprehensive and consistent stream temperature data throughout the CRB. The Watershed Health Temperature Dynamics use case goal is to determine instream habitat availability, while the Stream Temperature use case was focused on finding sources of temperature impairment. The use cases differ slightly in purpose, but the data necessary for each use case would be the same, so it was determined that they pair well together.

The format of the Needs Assessment Workshop allowed stakeholders with similar goals and objectives to bring forward and select the needs that were most important to them. This allowed for full formulation of thoughtful, informed use case development within each group. One potential concern with this approach is that needs which are very important to a large number of stakeholders may not have been selected as use cases. Because they were not one of the top three or four needs among individual groups, they were not selected as use cases by any groups, whereas topics of critical importance to a small number of stakeholders may have been chosen instead.

One example of an important use case that was potentially omitted would be drought monitoring and forecasting. Drought concerns were mentioned frequently early in the workshop, but none of the final developed use cases dealt with drought monitoring or forecasting.

Throughout the workshop, attendees mentioned that several key water management stakeholders were not present and would be a welcome and important addition to the discussion of needs in the CRB. Some of the absent stakeholders were designated as main decision makers or potential partners for use cases. Without representation at the workshop they were unable to speak to their current capabilities or operational challenges.

For example, the group did not include dam management agencies who make decisions that have basin-wide implications for flood control, recreation, irrigation, municipal applications, fish habitat and migration, hydropower, and tribal interests. Agencies that manage dams are especially important to the regulation and oversight of streamflow and stream temperature. These stream characteristics, while heavily dependent on natural inputs, are also carefully balanced by dam operations. Hydropower companies, in coordination with government agencies, are required to work together to maintain water supply while supporting watershed health.

Below is a list of the absent agencies that attendees recommended attend future needs assessment activities around the Columbia River Basin:

- BC Hydro
- Bonneville Power Administration
- Environmental Protection Agency
- Idaho Power
- U.S. Army Corps of Engineers
- U.S. Bureau of Reclamation

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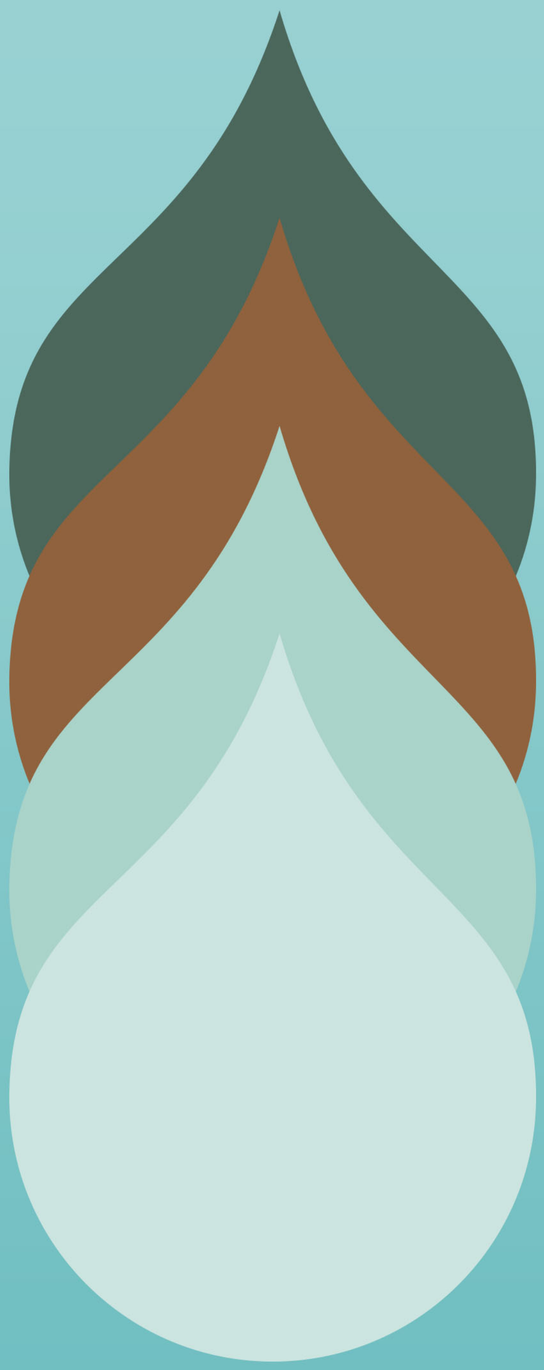

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